

CLAIMS

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1. A method of relieving congestion in a packet-based network that interconnects a plurality of peripheral networks by implementing corrective actions in said peripheral networks, said peripheral networks each comprising a plurality of switches, and said packet-based network comprising a plurality of gateway nodes having data to be transferred therebetween, and utilizing a concept of virtual pipelines between said gateway nodes, said pipelines comprising one or more channels, said method comprising the steps of:

(1) identifying a first set of virtual pipelines for which traffic exceeds a predetermined threshold;

15 (2) for each virtual pipeline in said set, determining a number of additional channels needed to cause said traffic through said pipeline to not exceed said predetermined threshold; and

20 (3) for each pipeline in said first set, assigning a corrective action and an amount of said corrective action to be taken in said peripheral networks as a function of said number of additional channels.

2. The method set forth in claim 1 wherein step (3) comprises the steps of assigning a call gapping rate for each

switch in the peripheral network contributing traffic to a pipeline for which traffic exceeds said predetermined threshold.

3. The method set forth in claim 2 wherein said call gapping rates are

$$\lambda_t - \lambda_N) / \lambda_t$$

where

λ_t is a call arrival rate for a corresponding pipeline;

and

λ_N is a call arrival rate corresponding to said predetermined threshold for said corresponding pipeline.

4. The method set forth in claim 3 wherein said predetermined threshold is a call blocking ratio and wherein step (2) comprises determining a minimum pipeline size that would reduce the call blocking ratio for said pipeline below said predetermined threshold based on a call arrival rate at said virtual pipeline and an average holding time per call.

5. The method set forth in claim 4 wherein said minimum pipeline size is expressed as a number of channels, M, in said pipeline and wherein step (2) comprises determining a number of channels M by;

$$B_M(\lambda_i / \mu) = \frac{(\lambda_i / \mu)^M / M!}{\sum_{n=0}^M (\lambda_i / \mu)^n / n!}$$

wherein

$$\rho(t) = \lambda(t) / \mu(t)$$

or

$$\rho'(t) = \lambda(t) - \rho(t) \mu(t)$$

6. The method set forth in claim 5 wherein

$\rho(t) = \lambda(t) / \mu(t)$ is used when call rate through said

pipeline has been historically increasing and

$\rho'(t) = \lambda(t) - \rho(t)\mu(t)$ is used when call rate through said

pipeline has been historically decreasing.

7. The method set forth in claim 4 wherein said network is an asynchronous transfer mode network.

8. The method set forth in claim 7 wherein said network is used to exchange voice data.

9. The method set forth in claim 8 wherein said other networks comprises time division multiplexed networks.

10. The method set forth in claim 1 wherein said corrective action comprises rerouting calls in said peripheral networks that would so that they pass through a different pipeline in said packet-based network.

5 11. The method set forth in claim 10 wherein said predetermined threshold is a call blocking ratio and wherein step (2) comprises determining a minimum pipeline size that would reduce the call blocking ratio for said pipeline below said predetermined threshold based on call arrival rate at said virtual pipeline and average holding time per call.

12. The method set forth in claim 11 wherein said minimum pipeline size is expressed as a number of channels, M, in said pipeline and wherein step (2) comprises determining a number of channels M by;

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$$B_M(\lambda_i / \mu) = \frac{(\lambda_i / \mu)^M / M!}{\sum_{n=0}^M (\lambda_i / \mu)^n / n!}$$

wherein

$$\rho(t) = \lambda(t) / \mu(t)$$

or

$$\rho'(t) = \lambda(t) - \rho(t)\mu(t)$$

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13. The method set forth in claim 11 wherein said network comprises a plurality of gateway nodes through which calls in said peripheral networks enter and exit said packet-based network and wherein step (3) comprises the steps of:

5 (3.1) determining a peak cell rate corresponding to said number of additional channels;

(3.2) determining if there is at least one gateway node corresponding to a source peripheral network for which there exists a path in said packet-based network to a destination node of said pipeline;

(3.3) determining if said path can accommodate a pipeline having said peak cell rate; and

(3.4) generating data indicating one or more alternate source gateways.

15 14. The method set forth in claim 13 further comprising the step of:

(3.5) outputting said data to said peripheral networks.

20 15. The method set forth in claim 13 further comprising the step of:

(4) organizing prior to step (3) said pipelines identified in step (1) in order of said number of additional channels determined in step (2); and

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wherein steps (3.1), (3.2), (3.3), (3.4) and (3.5) are performed for each pipeline identified in step (1) in order from said pipeline corresponding to said highest number of additional channels to said lowest number of additional channels.

16. The method set forth in claim 15 wherein step (3.2) comprises creating a list of all gateway nodes and wherein step (3.3) is performed with respect to each source gateway in said list of gateways until a source gateway having a path to said destination gateway that can accommodate a pipeline having said peak cell rate is located.

17. An apparatus for relieving congestion in a packet-based network that interconnects a plurality of peripheral networks by implementing corrective actions in said network, said packet-based network comprising a plurality of gateway nodes having data to be transferred therebetween, and utilizing a concept of virtual pipelines between gateway nodes of said network, said pipelines comprising one or more channels, said method comprising the steps of:

means for identifying a first set of virtual pipelines for which traffic exceeds a predetermined threshold;

means for determining, for each virtual pipeline in said set, a number of additional channels needed to cause said

traffic through said pipeline to not exceed said predetermined threshold; and

means for assigning, for each pipeline in said first set, a corrective action and an amount of said corrective action to be taken in said peripheral networks as a function of said number of additional channels.

18. The apparatus set forth in claim 17 wherein said means for assigning comprises:

means for assigning a call gapping rate for each peripheral network contributing traffic to a pipeline for which traffic exceeds said predetermined threshold.

19. The apparatus set forth in claim 18 wherein said call gapping rates are

$$\frac{\lambda_t - \lambda_N}{\lambda_t}$$

where

λ_t is a call arrival rate for a corresponding pipeline;

and

λ_N is a call arrival rate corresponding to said predetermined threshold for said corresponding pipeline.

20. The apparatus set forth in claim 19 wherein said predetermined threshold is a call blocking ratio and wherein said means for determining comprises determining a minimum pipeline size that would reduce the call blocking ratio for said pipeline below said predetermined threshold based on a call arrival rate at said virtual pipeline and an average holding time per call.

21. The apparatus set forth in claim 20 wherein said minimum pipeline size is expressed as a number of channels, M, in said pipeline and wherein step (2) comprises determining a number of channels M by;

$$B_M(\lambda_i / \mu) = \frac{(\lambda_i / \mu)^M / M!}{\sum_{n=0}^M (\lambda_i / \mu)^n / n!}$$

wherein

$$\rho(t) = \lambda(t) / \mu(t)$$

or

$$\rho'(t) = \lambda(t) - \rho(t)\mu(t)$$

22. The apparatus set forth in claim 21 wherein $\rho(t) = \lambda(t) / \mu(t)$ is used when call rate through said pipeline has been historically increasing and

$\rho'(t) = \lambda(t) - \rho(t)\mu(t)$ is used when call rate through said pipeline has been historically decreasing.

23. The apparatus set forth in claim 20 wherein said network is an asynchronous transfer mode network.

24. The apparatus set forth in claim 23 wherein said network is used to exchange voice data.

25. The apparatus set forth in claim 24 wherein said other networks comprises time division multiplexed networks.

26. The apparatus set forth in claim 17 wherein said corrective action comprises rerouting calls in said peripheral networks so that they pass through a different pipeline in said packet-based network.

27. The apparatus set forth in claim 26 wherein said predetermined threshold is a call blocking ratio and wherein said means for determining comprises determining a minimum pipeline size that would reduce the call blocking ratio for said pipeline below said predetermined threshold based on call arrival rate at said virtual pipeline and average holding time per call.

28. The apparatus set forth in claim 27 wherein said minimum pipeline size is expressed as a number of channels, M, in said pipeline and wherein step (2) comprises determining a number of channels M by;

$$B_M(\lambda_i / \mu) = \frac{(\lambda_i / \mu)^M / M!}{\sum_{n=0}^M (\lambda_i / \mu)^n / n!}$$

wherein

$$\rho(t) = \lambda(t) / \mu(t)$$

or

$$\rho'(t) = \lambda(t) - \rho(t)\mu(t)$$

29. The apparatus set forth in claim 27 wherein said network comprises a plurality of gateway nodes through which calls in said peripheral networks enter and exit said packet-based network and wherein said means for assigning comprises:

- means for determining a peak cell rate corresponding to said number of additional channels;
- means for determining if there is at least one gateway node corresponding to a source peripheral network for which there exists a path in said packet-based network to a destination node of said pipeline;
- means for determining if said path can accommodate a pipeline having said peak cell rate; and

means for generating data indicating one or more alternate source gateways.

30. The apparatus set forth in claim 29 further comprising:

5 means for outputting said data to said peripheral networks.

31. The apparatus set forth in claim 29 further comprising:

means for organizing said pipelines identified by said means for identifying said first set of virtual pipelines in order of said number of additional channels determined by said means for identifying; and

15 wherein said means for assigning acts on each pipeline identified by said means for identifying said first set of virtual pipelines in order from said pipeline corresponding to said highest number of additional channels to said lowest number of additional channels.

20 32. The apparatus set forth in claim 31 wherein said means for determining if there is at least said one gateway node comprises means for creating a list of all gateway nodes and wherein said means for determining if said path can accommodate a pipeline having said peak cell rate acts upon each source gateway in said list of gateways until a source

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gateway having a path to said destination gateway that can accommodate a pipeline having said peak cell rate is located.

33. A method of relieving congestion in a packet-based network that interconnects a plurality of peripheral networks by implementing corrective actions in said peripheral networks, said packet-based network comprising a plurality of nodes through which calls pass, said plurality of nodes including gateway nodes through which calls enter said packet-based network from said peripheral networks and exit said packet-based network to said peripheral networks, said method comprising the steps of:

(1) identifying a set of pairs of gateway nodes contributing traffic to individual ports of said packet-based network that are experiencing congestion above a predetermined threshold;

(2) for each pair of gateway nodes identified in step (1), assigning a bandwidth correction factor as a function of a fraction of calls between said pair of gateway nodes that would need to be blocked to meet said threshold for a port to which that pair of gateway nodes is contributing traffic that is most congested;

(3) for each pair of gateway nodes identified in step (1), assigning a corrective action and an amount of said corrective action to be taken in said peripheral networks as a function of said bandwidth correction factor.

34. The method set forth in claim 33 wherein step (3) comprises the steps of assigning a call gapping rate for each peripheral network contributing traffic to a port for which traffic exceeds said predetermined threshold.

5 35. The method set forth in claim 34 wherein said call gapping rates are

$$\frac{(\lambda_t - \lambda_N)}{\lambda_t}$$

where

λ_t is a call arrival rate for a corresponding pipeline;

and

λ_N is a call arrival rate corresponding to said predetermined threshold for said corresponding pipeline.

15 36. The method set forth in claim 33 wherein step (1) comprises the steps of:

(1.1) comparing a present utilization of each port to a utilization threshold; and

(1.2) for each port with present utilization exceeding said threshold, finding a set of pairs of gateway nodes contributing calls through said port.

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37. The method set forth in claim 36 wherein said threshold comprises a delay jitter parameter.

38. The method set forth in claim 36 wherein said threshold comprises a packet loss parameter.

5 39. The method set forth in claim 36 wherein said threshold comprises a delay jitter parameter and a packet loss parameter.

40. The method set forth in claim 36 wherein step (3) comprises:

(3.1) for each port identified in step (2), determining the number of calls per second that can be accommodated at said port without exceeding said threshold;

(3.2) for each port identified in step (2), determining the ratio by which the actual number of calls per second through said port exceeds said threshold; and

15 (3.3) for each pair of gateway nodes that is contributing traffic to at least one congested port, assigning to said pair of gateway nodes a voice compression ratio corresponding to the port to which it is contributing traffic

20 that is most congested.

41. The method set forth in claim 40 wherein step (3.1) comprises solving:

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$$T = \frac{(\alpha_c / \mu)^c / c!}{\sum_{n=0}^c (\alpha_c / \mu)^n / n!}$$

for α_c , where

C is a number of calls that can be accommodated at the port as determined by said threshold,

$1/\mu$ is an average holding time per call, and

α_c is said number of calls per second that can be accommodated at that port.

42. The method set forth in claim 41 wherein step (3.2) comprises the step of solving

$$\alpha_A = \sum_{j=0}^M \lambda_{Ri,j}$$

where α_A is an average arrival rate for calls between pairs of nodes in said set of gateway nodes contributing traffic to said port.

43. The method set forth in claim 42 wherein said bandwidth correction factor are derived by

$$\rho_{B_i} = (\alpha_A - \alpha_c) / \alpha_A$$

where ρ_{BL} is said bandwidth correction factor.

44. The method set forth in claim ³³~~8~~ wherein said corrective action comprises re-routing calls in said peripheral networks.

45. The method set forth in claim 44 wherein step (3) comprises the steps of:

(3.1) for each pair of gateway nodes identified in step 1, determining a number of extra channels needed to reduce traffic below said threshold;

(3.2) determining if there is at least one gateway node corresponding to a source peripheral network for which there exists a path in said packet-based network to a destination node of said pipeline;

(3.3) determining if all ports through which said path traverses have present utilization less than their utilization thresholds.

(3.4) generating data indicating one or more alternate source gateways.

46. The method set forth in claim 45 further comprising the steps of:

(3.5) outputting said data to said peripheral networks.

47. The method set forth in claim 46 further comprising the step of:

(4) ordering prior to step (3), said pipelines identified in step (1) in order of said number of extra channels determined in step (2); and

wherein steps (3.1), (3.2), (3.3), (3.4) and (3.5) are performed for each pipeline identified in step (1) in order from said pipeline corresponding to said highest number of extra channels to said lowest number of extra channels.

48. The method set forth in claim 47 wherein step (3.2) comprises creating a list of all gateway nodes and wherein step (3.3), (3.4) and (3.5) are performed for each path in said list created in step (3.2).

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